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Evaluation of resistance of the groundnut seed beetle, *Caryedon serratus* Ol. (Coleoptera, Bruchidae) to different formulations of insecticides.

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ABSTRACT
Objectives: This study aimed to determine the level of resistance of different strains of the groundnut seed beetle, *Caryedon serratus* against some synthetic insecticides formulas and to compare their biodemographic parameters.
Methodology and results: The insecticides tests were done in three localities of Senegal (Mpal, St-Louis and Sedhiou) using two formulations: powder (Propoxur®) and liquid (Deltamethrin®). The results indicated that the mortality varied according to the locality, the applied doses or concentrations and to the exposure time. Mortality rate rose to 100% within the 48 hours after the application of high doses, which followed the Propoxur treatment, while the low rates are observed after the application of the smallest doses (D1 and D2). Mortality with Deltamethrin treatment was usually low, as high rates were obtained with the highest concentration. A progeny of tested adults (survivors) is only obtained with small doses of Propoxur and Deltamethrin.
Conclusions and application findings: This study has enabled us to see that products used had effects together on the adults tested and on their progeny. The Individuals from Sedhiou seemed to show more resistance to both products. Therefore, to better assess the resistance of groundnut bruchid, *C. serratus* to insecticides, the implication of genetic characterization is needed. Because of the resistance genes of this pest could be constitute an important tool for an integrated pest management.
Keywords: Groundnut, *Caryedon serratus*, Deltamethrin, Propoxur, Resistance, Bio-demographic.

INTRODUCTION

The post-harvest losses caused by insect pests of stored foodstuffs amounted to 10% in average on a global scale for an annual monetary value estimated about 58 billion USD (Goergen, 2005). In Senegal, groundnut, the main annuity crop covers more than half of the arable surfaces, and reported each year for a value of 80 billion CFA francs, which is equivalent to 40% of the total exports of the country

(Sembene, 2000). This legume very used for its intake of nutrients (proteins, fats, fibres, minerals and vitamins) suffered to various attacks which the most important are caused by a beetle of the family of Bruchidae, *Caryedon serratus.* The damage caused by this pest on the production of groundnut of Senegal can go up to 83 % of quantitative wastes after a storage period of four months (Ndiaye, 1991). However, losses occur in all stages from stocks for the next seeds to those intended for marketing and consumption. The responses to struggle these major pests of stocks have been essentially chemicals (Gueye *et al*., 2011). However, the use of increased quantities of insecticides does not represent only a danger to the environment but has also led to the formation of individual resistance (ability to survive and to reproduce despite the presence of the toxic compounds in their environment). The three types of resistance mechanisms known are behavioural, physiological and biochemical (Magnin *et al*., 1985; Haubruge and Amichot, 1998). The resistance of Caryedon *serratus* has not been revealed. It is advisable to conduct sensitivity tests on this beetle to learn more about its behaviour in the face of insecticides. Similar studies were realized on *Callosobruchus maculatus* and showed promising results. It is from this perspective that our study aimed to determine the level of resistance of *Caryedon serratus* using certain formulations of insecticides and to compare the biodemographic parameters of the different strains.

MATERIAL AND METHODS

Sampling: The samples were collected from four localities of Senegal namely: Mpal (15°55'19"Nand 16°16'02"W), Saint -Louis (16°04'00"Nand 16°30'00"W), located in the agro-ecological area of Senegal River Valley; and Diana Malary (12°50'54"Nand 15°14'59"W) situated in the region of Sedhiou in lower Casamance agro-ecological area. The Northern area is very favourable to the culture of groundnuts (but ability often limited by depletion of the soil and the rainfall deficit); however, the Senegal River Valley and the Lower Casamance have a strong potential in natural resources with important water resources. Groundnut samples were bought in storage structures and conveyed to the laboratory to be preserved in glass jars. Adults who have emerged from the seeds have been used for mass breeding.

Mass breeding: It is performed in order to obtain a relatively large number of individuals for the tests. The insects used came from the groundnuts of study sites. A large number of adults (male and female) are introduced in Petri dishes glass containing seeds of groundnut previously frozen (in order to eliminate any trace of primary infestation) and brought back to ambient temperature. The insects of each locality were removed 48 hours later and placed in new boxes containing healthy seeds. The previous boxes are left on the bench at room temperature (28 to 31.5°C) with a relative humidity of 40 -68% until the appearance of cocoons, which will be isolated in boxes with, wells by reason of one per hole until emergence of adults. The name of localities is mentioned above each box. The breeding boxes are left at laboratory temperature.

Evaluation of the sensibility of *Caryedon serratus:* Toxicity tests are carried out by contact in Petri dishes (95mm Ø) in ambient temperature conditions. They are made with five (5) couples of individuals of *C. serratus* (generation F1) in the presence of 30g of groundnuts. These couples are exposed to different doses and each test is repeated three times. The control tests are made for each locality.

 For the PROPOXUR, formulation in powder, eight (8) doses are applied:

D1= 0.01 g; D2= 0.02 g; D3= 0.1g; D4= 0.2 g; D5= 0.4 g; D6= 0.6 g; D7= 0.8g and D8 = 1g.

Each dose is powdered in boxes in presence of 30g of groundnuts and all is homogenized well before the introduction of couples.

 For the DELTAMET 25 EC, liquid formulation containing 25g/L of active ingredient, six concentrations are applied. The recommended dosage is 40ml for 30L of water, dosage brought back to 1L of water allowed to determine the concentration Cx from which four (4) other concentrations are:

C1=Cx/4= 0.325ml/L ; C2=Cx/2= 0.65ml/L ; C3=Cx= 1.3ml/L ; C4=Cx×2= 2.6ml/L et C5=Cx×4= 5.2ml/L.

For each concentration, 1ml is collected using a PIPETMAN and is introduced into the boxes before the insertion of couples.

Calculated Parameters: The number of dead insects or in state of “Knock Down” (KD) is raised every 24 hours.

The mortality rate of adults tested is then calculated and corrected by the formula of Abbot (1925):

$$\%\text{corrected} = \left(1 - \frac{\text{n in T after treatment}}{\text{n in Co after treatment}}\right) \times 100$$

Where: n= insect population T=Test Co=Control

If there are any survivors, these latest are left in the boxes and are removed a week after. The new generation stemming from these tests (the generation F2) are the "survivors". These last are coupled with new, due to one couple by box. Various data are collected:

- The number of eggs laid: is the number of eggs deposited on the surface of seeds
- The number of formed cocoons
- The rate of emergence (TE) which corresponds to the ratio between the total number of emerged adults and the total number of laid eggs
- The duration of larval development: it is the time between the emergence of the eggs on a seed and the formation of the cocoon.
- The duration of total development: it is the time between the emission of an egg on a seed and an emergence of the adult that arises from the latter.
- Sex ratio: it gives the percentage of females compared with all the descendants. If the sex ratio is higher than 50 %, it is in favour of females in the otherwise it is in favour of males.
- The data obtained allowed to establish tables of life, which showed some biological parameters among the most characterising the life of an insect: $\mathbf{r_m}$, $\mathbf{R_0}$, $\mathbf{t_d}$, $\mathbf{L_{max}}$, $\mathbf{T_s}$.
- r_m is the daily intrinsic growth rate. This is the most common used parameter (Cancela Da Fonseca, 1975; Delobel and Unnithan, 1983; Harari *et al.*., 1997).

According to Birch (1953), despite the fact that natural populations never have a distribution of stable age, the intrinsic rate of growth r_m is a useful concept for experimental thorough studies on the distribution and abundance of animals in fields. In addition to the nature of food, it depends on the temperature and humidity of air. If x is the age of females, lx the proportion of females alive in the day x and mx the number of descendants females arisen from a female of age x in x+1,
have:
$\mathbf{\sum 1_x . m_x . e^{-r} m^x = 1}$. It can be express otherwise,
r_m= log£ where £ is the rate of multiplication per female per day. Pielou (1974) assimilated the r_m to a rate of interest, while £ is the support of the size of the population for two given moments, separated by a unit of time. r_m is an instantaneous rate, £ a finite rate. According to this author, when a population grows exponentially, it must have a stable distribution. This means that the proportions of individuals of different age classes must remain identical to themselves. This occurs when a population of each stage considered as a single entity, is still growing at the same rhythm. Each stage gets members when individuals leave the stage (die or moult). Nevertheless, the distribution remains stable if individuals' proportion in each age class remains constant.

- R_0 is the net rate of reproduction. In other words, it is the number of descending females from one given female. It appears as one of the most eloquent parameters of the demography of an insect. $\mathbf{R_0 = \sum 1x.mx}$. Pielou (1974) also defines it as the relationship of the total number of born in a generation among births in the previous generation.
- Td is the doubling time of the stable population, td=log2/rm
- Lmax is directly read on the tables of life, it represents the age of the last female surviving from the egg.

Statistical analysis: The collected data were recorded on Excel 2007 and submitted to an analysis of variance (ANOVA) using XLSTAT software version 6.1.9. The multiple comparisons of means were done according to the test of Tukey-Kramer at the significant threshold of 5%.

RESULTS

Evolution of mortality according to different localities at the end of week: According to the applied product, the mortality rate varied depending on the dose and the locality of origin of the strains studied (Figure 1A). The populations of Saint- Louis and Sedhiou recorded the lower mortality rate with the two insecticides used. However, in Sedhiou mortality reached 50% with the higher concentrations (C4 and C5) of the Deltamethrin (Figure 1B).

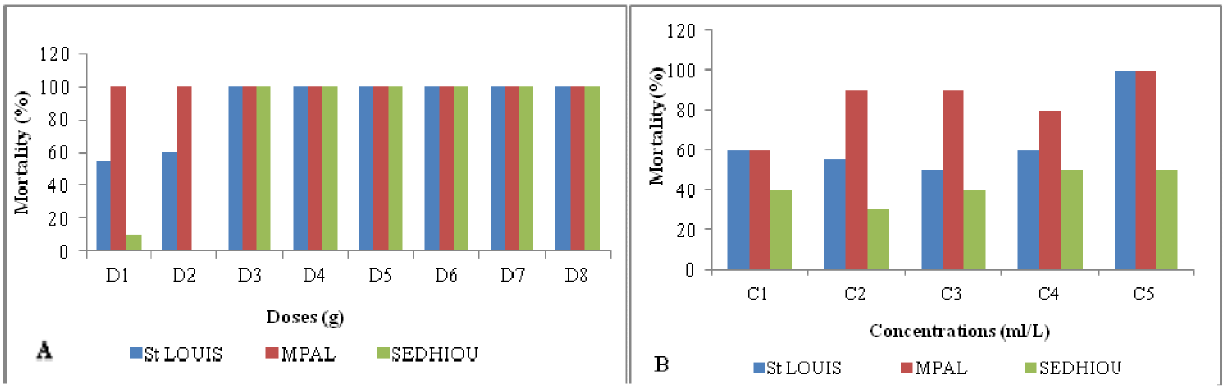

Figure 1: Evolution of mortality rate of different strains of *Caryedon serratus* depending on the dose (A) or concentration (B) insecticides at the end of week.

Development time of survivors: Table 1 showed that the duration of development depended on the locality and the dose of insecticide applied. There is no significant difference noted between the control (W) and the survivors of each locality for the duration of larval development. Furthermore, a slight reduction of the nymphal phase is noticed in St-Louis and Mpal while in Sedhiou this last is longer in the survivors than among the witness. The surviving adults took longer to develop in Saint -Louis and Sedhiou areas while in Mpal they developed more rapidly than the control did (71 days against 73.3).

Table 1: Average duration development of survivors treated with Propoxur.

Localities	Doses	Larval development ± Standard Deviation	Nymphal development ± Standard Deviation	Total development ± Standard Deviation
Saint- Louis	W	39.09[(a)] ± 10.32	32.76[(a)] ± 10.25	71.85[(a)] ± 20.42
	D_1	45.71[(a)] ± 10.80	32.41[(b)] ± 10.39	78.12[(b)] ± 21.04
	D_2	-	-	-
Mpal	W	47.25[(a)] ± 7.58	26.05[(a)] ± 6.85	73.30[(a)] ± 14.40
	D_1	45[(a)] ± 1.41	26[(b)] ± 11.31	71[(b)] ± 12.73
	D_2	-	-	-
Sedhiou	W	79[(a)] ± 13.48	23.80[(a)] ± 3.94	102.80[(a)] ± 17.02
	D_1	81.53[(a)] ± 15.27	59.35[(b)] ± 15.56	140.88[(b)] ± 30.81
	D_2	82.86[(b)] ± 17.61	64.64[(c)] ± 12.19	147.50[(c)] ± 29.74

-: not defined; a, b, c: Means within a column with no common superscripts differ significantly ($p < 0.05$).

It is noted that no survivors to Deltamethrin has been obtained in Mpal and in Saint -Louis, they are obtained only with the concentration C1 (Table 2). Duration Development of survivors depended on the locality and the applied concentration. The larval stage is longer in Sedhiou; we noted elsewhere in this locality an average reduction of about 7 days for concentrations ranging from C2 to C4 by report to the control and a lengthening of this phase in C5 (104.33 days versus 79 for the control). In Saint- Louis, the larval stage is longer after treatment of 54 days versus 39.09 in the control. The nymphal duration is much longer at the survivors than the control as well in Sedhiou as in Saint Louis (50 days to 73.47 respectively in C5 and C2 against 23.80 days in Sedhiou and 43.67 days against 32.76 in Saint -Louis). The duration of total development is also longer at the survivors in these two localities.

Demographic evolution parameters

Life cycle of surviving adults: The results showed that there is no significant difference of life duration between survivors and control: counter to in absolute value, the survivors of different localities lived more than the control (Table 3) did.

Table 2: Average duration of development of survivors treated with Deltamethrin

Localities	Concentrations	Larval development ± Standard Deviation	Nymphal development ± Standard Deviation	Total development ± Standard Deviation
Sedhiou	W	79[(a)] ± 13.48	23.80[(a)] ± 3.94	102.80[(a)] ± 17.02
	C_1	79.09[(bc)] ± 14.10	54.18[(b)] ± 13.09	133.27[(b)] ± 27.13
	C_2	71.94[(bc)] ± 13.30	73.47[(b)] ± 16.74	145.41[(b)] ± 29.98
	C_3	73.37[(bc)] ± 16.28	70.26[(b)] ± 18.10	143.63[(b)] ± 34.23
	C_4	69.25[(bc)] ± 21.17	67[(b)] ± 18.92	136.25[(b)] ± 40.02
	C_5	104.33[(c)] ± 10.21	50[(ab)] ± 15.62	154.33[(b)] ± 25.81
Saint-Louis	W	39.09[(a)] ± 10.32	32.76[(a)] ± 10.25	71.85[(a)] ± 20.42
	C_1	54[(b)] ± 11.79	43.67[(b)] ± 12.34	97.67[(b)] ± 24.13
	C_2	-	-	-
	C_3	-	-	-
	C_4	-	-	-
	C_5	-	-	-

-: not defined; a, b, c: Means within a column with no common superscripts differ significantly ($p < 0.05$).

Table 3: Average longevity of surviving adults to the treatment with Propoxur.

Localities	Doses	Life expectancy of females ± Standard Deviation	Life expectancy of males ± Standard Deviation
Saint - Louis	W	26.82[(a)] ± 5.19	24.88[(a)] ± 5.60
	D_1	27.71[(a)] ± 7.95	26.06[(a)] ± 6.76
	D_2	-	-
Mpal	W	23.40[(a)] ± 9.59	21.30[(a)] ± 11.80
	D_1	35[(a)]	33[(a)]
	D_2	-	-
Sedhiou	W	19.40[(a)] ± 3.81	15.50[(a)] ± 2.51
	D_1	31.24[(a)] ± 10.45	33.24[(a)] ± 8.10
	D_2	28.21[(a)] ± 5.47	29.57[(a)] ± 5.24

-: not defined; a, b, c: Means within a column with no common superscripts differ significantly ($p < 0.05$).

Table 4 showed that the life expectancy of survivors depended on the locality and the concentration of Deltamethrin used. In Sedhiou, it is longer than the control as well in females than in males. In contrast, in Saint –Louis, the females who had survived to the treatment with C1 lived less than control (23 days against 26.82). The opposite is noted in males where the difference between survivors and control is about 9 days.

Tableau 4: Average longevity of surviving adults to the treatment with Deltamethrin.

Localities	Concentrations	Life expectancy of females ± standard deviation	Life expectancy of males ± standard deviation
Sedhiou	W	19.40[(a)] ±3.81	15.50[(a)] ± 2.51
	C_1	40.55[(b)] ± 7.58	32.18[(b)] ± 3.19
	C_2	37.71[(b)] ± 6.51	33.35[(b)] ± 7.98
	C_3	37.74[(b)] ± 9.13	36.11[(b)] ± 6.77
	C_4	36.25[(b)] ± 7.94	31.13[(b)] ± 7.78
	C_5	27[(ab)]	33.33[(b)] ± 5.86
Saint - Louis	W	26.82[(a)] ± 5.19	24.88[(a)] ± 5.60
	C_1	23[(b]	33.67[(b)] ± 7.09
	C_2	-	-
	C_3	-	-

	C_4	-	-
	C_5	-	-

-: not defined; a, b: Means within a column with no common superscripts differ significantly (p< 0.05).

Laying of the survivors: The analysis of the table 5 revealed that the number of eggs laid by the survivors depended on the locality; there is a reduction of the activity of heavyweight in Saint Louis and Mpal localities; whereas in Sedhiou, females stemming from tests with the dose D1 emitted more eggs.

Table 5: Laying of the survivors to the treatment with Propoxur

Localities	**Control**	**D_1**	**D_2**
Saint- Louis	$55.77^{(a)} \pm 23.86$	$43.09^{(a)} \pm 17.85$	-
Mpal	$61.18^{(a)} \pm 17.84$	$25^{(a)}$	-
Sedhiou	$42.83^{(a)} \pm 20.77$	$45.13^{(a)} \pm 25.04$	$40.50^{(a)} \pm 13.29$

-: not defined; a, b: Means within a row with no common superscripts differ significantly (p< 0.05).

The results given in table 6 showed that the laying of surviving females is affected by the treatment with Deltamethrin. Indeed, the results showed that the number of emitted eggs varied according to the locality and the concentration of insecticide (p< 0.05). We have recorded in Saint -Louis a decrease of the number of emitted eggs (42 against 55.77 for control); In Sedhiou, there is a decrease or an increase of this number according to the concentration.

Table 6: Laying of the survivors to the treatment with Deltamethrin

Localities	**Control**	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
Sedhiou	$42.83^{(b)} \pm 20.77$	$44^{(ab)} \pm 17.61$	$35.65^{(ab)} \pm 22.82$	$29.77^{(a)} \pm 26.55$	$34.83^{(ab)} \pm 23.45$	$73^{(b)}$
Saint- Louis	$55.77^{(b)} \pm 23.86$	$42^{(ab)}$	-	-	-	-

-: not defined; a, b: Means within a row with no common superscripts differ significantly (p< 0.05).

Sex-ratio and emergence rate of adults stemming from the survivors: The Table 7 showed that the emergence rate varied according to the dose and the locality, we note an increase of the rate in all localities except in Sedhiou where there is a considerable decrease of this rate for adults tested by report to the control. The analysis of the results revealed that there is no significant difference between the doses in the sex-ratio, which is in favour of males except in Mpal where females are more numerous. However, in Saint- Louis it is in favour of females for adults tested and not for the control.

Table 7: Emergence rate and sex- ratio of the descendants of survivors treated with Propoxur.

Localities	**Doses**	**Emergence rate (T.E)**	**Sex-ratio (R)**
Saint Louis	W	$60.69^{(b)} \pm 21.70$	$47.07^{(a)} \pm 11.16$
	D_1	$61.38^{(b)} \pm 23.29$	$51.71^{(a)} \pm 10.35$
	D_2	-	-
Mpal	W	$46.06^{(b)} \pm 21.28$	$58.38^{(a)} \pm 12.34$
	D_1	$72^{(b)}$	$55.56^{(a)}$
	D_2	-	-
Sedhiou	W	$80.88^{(b)} \pm 31.71$	$48.73^{(a)} \pm 8.20$
	D_1	$36.27^{(b)} \pm 16.22$	$49.55^{(a)} \pm 16.86$
	D_2	$28.27^{(a)} \pm 12.02$	$44.51^{(a)} \pm 20.04$

-: not defined; a, b: Means within a column with no common superscripts differ significantly (p< 0.05).

The results given in the table 8 showed a significant decrease in the emergence rate of adults compared to control in the two localities. The sex-ratio is in favour of males in Saint Louis, whereas in Sedhiou, it varied depending on the concentration and it is in favour of females for the concentrations C3 to C4.

Table 8: Emergence rate and sex- ratio of the descendants of survivors treated with Deltamethrin.

Localities	Concentrations	Emergence rate (T.E)	Sex-ratio (R)
Sedhiou	W	80.88(a) ± 31.71	48.73(a) ± 8.20
	C_1	31.32(a) ± 4.73	45.20(a) ± 12.32
	C_2	33.22(a) ± 21.28	52.65(a) ± 23.79
	C_3	32.89(a) ± 15.03	59.05(a) ± 17.07
	C_4	39.35(a) ± 17.30	50.37(a) ± 20.24
	C_5	27.40(a)	40(a)
Saint- Louis	W	60.69(a) ±21.70	47.07(a) ± 11.16
	C_1	28.57(a)	25(a)
	C_2	-	-
	C_3	-	-
	C_4	-	-
	C_5	-	-

-: not defined; a, b: Means within a column with no common superscripts differ significantly ($p < 0.05$).

Duration of Development of adults stemming from the survivors: The development duration of the survivor's descendants (Table 9) depended on the locality and the dose of insecticide. The larval stage of the survivors is longer than the one of control in all localities. The same trend was noted for durations of nymphal and total development.

Table 9: Average duration of development of the descendants of survivors treated with Propoxur.

Localities	Doses	Larval development ± standard deviation	Nymphal development ± standard deviation	Total development ± standard deviation
Saint Louis	W	65.26(a) ± 4.67	62.71(b) ± 6.62	119.16(b) ± 9.59
	D_1	79.64(b) ± 9.23	66.19(b) ± 11.44	131.30(b) ± 11.88
	D_2	-	-	-
Mpal	W	68.58(a) ± 5.53	64.33(b) ± 5.68	122.75(b) ± 8.92
	D_1	73.83(b)	66.92(b)	139.58(b)
	D_2	-	-	-
Sedhiou	W	43.47(a) ± 5.61	25.33(b) ± 2.07	62.68(b) ± 4.11
	D_1	65.71(b) ± 13.73	35.34(b) ± 18.03	93.63(b) ± 27.59
	D_2	62.36(a) ± 8.18	33.21(a) ± 4.23	86.24(a) ± 18.83

-: not defined; a, b: Means within a column with no common superscripts differ significantly ($p < 0.05$).

The larval and nymphal development duration (Table 10) of the adult's descendants treated with the different concentrations showed significant differences ($p < 0.05$) compared to that of control. Indeed, these phases were longer in the progeny derived from the tests in Sedhiou; the longest durations are obtained in the treatment with C1 (86.30 days against 43.47 for the larval stage and 42.61 days against 25.33 for the nymphal stage). In contrast, in Saint Louis, the nymphal stage is shorter in descendants with a difference larger than 15 days in relation to the control. The duration of total development depended on the locality with a long development duration in Saint -Louis. However, this duration is delayed in the two areas compared with the control; the longest duration is noted with C1 (121.33 days in Sedhiou and 127.08 in Saint- Louis).

Table 10: Average development duration of the survivor's descendants treated with Deltamethrin.

Localities	Concentrations	Larval development ± standard deviation	Nymphal development ± standard deviation	Total development ± standard deviation
Sedhiou	W	43.47[(a)] ± 5.61	25.33[(b)] ± 2.07	62.68[(a)] ± 4.11
	C_1	86.30[(b)] ± 6.98	42.61[(ab)] ± 7.63	121.33[(a)] ± 11.41
	C_2	79.27[(ab)] ± 25.05	31.50[(a)] ± 11.33	104.49[(a)] ± 36.39
	C_3	68.81[(ab)] ± 20.13	33.12[(a)] ± 8.43	91.25[(a)] ± 27.78
	C_4	67.97[(ab)] ± 24 .72	35.38[(a)] ± 17.37	106.10[(a)] ± 20.47
	C_5	64[(a)]	37.32[(a)]	98.47[(a)]
Saint - Louis	W	65.26[(a)] ± 4.67	62.71[(b)] ± 6.62	119.16[(a)] ± 9.59
	C_1	88.14[(b)]	46.85[(ab)]	127.08[(a)]
	C_2	-	-	-
	C_3	-	-	-
	C_4	-	-	-
	C_5	-	-	-

-: not defined; a, b: Means within a column with no common superscripts differ significantly ($p< 0.05$).

Growth parameters of adults stemming from the survivors: The results given in table 11 showed that the growth parameters of different strains of *C. serratus* are affected by the treatments performed. The daily intrinsic growth rate (r_m) which is higher in Saint -Louis presented a reduction in the various localities; so in Sedhiou it is about 3%. The net rate of reproduction of survivor's progeny didn't show any significant difference compared to that of control ; except in Sedhiou where there is a significant decrease in this rate (4.93 % against 16.89 %).The population of the progeny is grown faster than that of control at the end of the treatment in all the studied areas (7 days in Saint -Louis, 4 in Mpal at D1; 2 and 1 days in Sedhiou at D1 and D2). No significant differences are noticed for the age of the last female to survive from the couple treated, on the contrary in Sedhiou the latter is older in the progeny of the survivors than to the control (96.21 days against 78.56).

Table 11: Average growth parameters of survivor's descendants treated with Propoxur.

Localities	Doses	r_m	R_0	T_d	L_{max}
Saint- Louis	W	12.16[(c)] ± 1.55	15.67[(b)] ± 9.16	10.51[(c)] ±6.05	141.20[(b)] ± 10.90
	D_1	10.83[(b)] ± 2.58	13.64[(b)] ± 6.84	7.03[(b)] ±3.97	144.86[(b)] ± 15.17
	D_2	-	-	-	-
Mpal	W	11.26[(c)] ± 1.91	15.68[(b)] ± 7.89	8.10[(c)] ±4.87	137.71[(b)] ± 8.63
	D_1	10.02[(b)]	10[(b)]	4.64[(b)]	143[(b)]
	D_2	-	-	-	-
Sedhiou	W	10.78[(c)] ± 1.53	16.89[(b)] ± 5.84	7.66[(c)] ± 3.23	78.56[(b)] ± 10.69
	D_1	7.89[(b)] ± 2.26	6.56[(b)] ± 3.65	2.48[(b)] ± 1.74	95.06[(b)] ± 13.59
	D_2	7.91[(a)] ± 1.58	4.93[(a)] ± 3.08	1.80[(a)] ± 0.94	96.21[(a)] ± 14.37

-: not defined; a, b, c: Means within a column with no common superscripts differ significantly ($p< 0.05$).

The table 12 showed the growth parameters of the survivor's descendants treated with Deltamethrin. The results revealed that the daily growth rate is decreasing in the progeny derived from tests for the two areas except for C5 in Sedhiou where we noted a slight increase of this rate. The examination of the results allowed us to see that the treatments have led to a considerable decrease in the number of female descendants in relation to the control in the two areas. It also showed that the population doubling time of control is longer than that of the survivors' descendants. The last female, which is survived from the couple in Saint- Louis, is older than that of Sedhiou; however, in this latest, the Lmax is higher in the survivors' descendants than to control with a high value in C1 (126.5 days against 78.56).

Table12: Average growth parameters of survivors' descendants treated with Deltamethrin.

Localities	Concentrations	r_m	R_0	T_d	L_{max}
Sedhiou	W	$10.78^{(b)} \pm 1.53$	$16.89^{(b)} \pm 5.84$	$7.66^{(b)} \pm 3.23$	$78.56^{(a)} \pm 10.69$
	C_1	$7.94^{(a)} \pm 0.43$	$6^{(a)} \pm 2.16$	$2.67^{(a)} \pm 0.51$	$126.5^{(a)} \pm 9.11$
	C_2	$6.27^{(a)} \pm 3.38$	$5^{(a)} \pm 3.79$	$1.71^{(a)} \pm 1.52$	$103.47^{(a)} \pm 31.17$
	C_3	$4.60^{(a)} \pm 1.91$	$5.38^{(a)} \pm 5.35$	$0.98^{(a)} \pm 0.96$	$114^{(a)} \pm 9.95$
	C_4	$5.22^{(a)} \pm 2.32$	$5.92^{(a)} \pm 4.08$	$1.65^{(a)} \pm 1.61$	$108.42^{(a)} \pm 40.08$
	C_5	$10.94^{(ab)}$	$8^{(ab)}$	$5.02^{(ab)}$	$101^{(a)}$
Saint -Louis	W	$12.16^{(b)} \pm 1.55$	$15.67^{(b)} \pm 9.16$	$10.51^{(b)} \pm 6.05$	$141.20^{(a)} \pm 10.90$
	C_1	$7.95^{(a)}$	$3^{(a)}$	$1.74^{(a)}$	$140^{(a)}$
	C_2	-	-	-	-
	C_3	-	-	-	-
	C_4	-	-	-	-
	C_5	-	-	-	-

-: not defined; a, b: Means within a column with no common superscripts differ significantly ($p < 0.05$).

DISCUSSION

The obtained results showed that the mortality due to Propoxur treatments at the end of a week varied according to the applied doses. The localities of Sedhiou and Saint- Louis recorded 100% of mortality only from the dose D3; whereas, this rate was 100% at all doses in Mpal. Other authors also have satisfactory results by testing the action of plants with insecticide effects on crop pests. Thiaw *et al*. (2007) and Zoheir *et al.* (2011) have also observed 100% of mortality rate in six days by using powders of *Calotropis procera* and *Senna occidentalis* on adults of *C. serratus* and essential oils of *Origanum glandulosum* on adults of *Acanthoscelides obtectus*. The survivors (progeny of adults tested) were obtained only with the low doses (D1and D2). The high doses causing high mortalities within 24h which followed the treatment that leaving not to adults the time to mate. These results corroborated to those of Doumma *et al.* (2011), who have assessed the action of the leaves of *Boscia senegalensis* on *C. maculatus*. Our results are also in agreement with those of Mazibur and Gerhard (1999) and Ketoh *et al.* (2002). As regards to the duration of development of survivors, an elongation or a shortening of the total duration was recorded depending to the locality and the used doses. This situation could be explained by the diminution or augmentation of an intermediate phase to the detriment of the other. A similar observation was made by Thiaw and Sembene (2010), by comparing the control of *C. serratus* to the adults treated with extracts of *Calotropis procera*. However, according to these authors, the development duration did not vary depending on different concentrations, but rather based on the sample. The individuals can develop rapidly in Mpal. This situation could be resulted from a certain adaptation by these insects following a strong use of the product in this area, which would allow them to develop despite its presence. This would highlight a resistance towards this insecticide, which would result in the acceleration of the cycle of development of the individuals of this locality. The results showed no differences under the doses for the longevity of survivors and their laying as well as for the emergence rate and sex-ratio of their progeny. However, the absolute values showed that the survivors of the different localities lived longer. In addition, Propoxur would play an inhibitive role in the process of reproduction of adults with as effect on the reduction of the laying of females; the contrary is noted in Sedhiou for the survivors from the D1 dose. Generally, the rate of emergence increase except in Sedhiou. Propoxur had no effect on the sex-ratio except in Saint- Louis where it was in favour of females. The duration of development of the survivor's descendants is elongated compared to controls. The Propoxur would have an effect of delaying the development of the descendants. The analysis of the growth parameters showed that it would also have an effect of reducing certain parameters such as the growth rate of daily intrinsic (rm), the net rate of reproduction (R0) and an increase of the age of the last female (Lmax). However, it could be at the origin of a demographic explosion, the population of progeny doubling faster in various localities. The analysis of the rate mortality with Deltamethrin showed no statistical differences between the different modalities (no locality effect, no dose effect and no exposure time effect). By contrast, differences are observed if we compare the data in absolute value. The mortality was low in general and did not exceed 50% during the different exposure time. Some phenomena have been remarked by the presence of this insecticide, particularly the states of "Knock-Down" (KD) in which were submerged some individuals. Indeed, according to Farhan (1973), organochlorines and pyrethroids produced a characteristic reaction resulting in a sudden paralysis of the insect; this reaction, which may eventually disappear if the dose is not fatal. Cumulative mortality at the end of a week showed a significant difference between the communities. The rates were higher in Mpal and Saint - Louis and lower in Sedhiou. Furthermore, the recommended dose (C3= 1.3 ml/L) of Deltamethrin could eliminate 40.50 and 90% of individuals respectively in Sedhiou, Saint -Louis and Mpal. It was only at the highest concentration C5 that it got 100% of mortality in Mpal and Saint- Louis; on the contrary, Affo-Dogo (2013) obtained the same percentage on *Callosobruchus maculatus* at 1mg/g after 24h of treatment in all studied areas. This situation could be due to the morphological or anatomical differences of the two species. Our results were similar to those of Faye *et al.* (2012) who have reported100 % of mortality in 7 days with the highest concentration of the aqueous extracts of *Crateva religiosa* tested on *C.maculatus*. Other authors have shown interesting results by obtaining a mortality rate of 100% on *Caryedon serratus* with fraction methalonique extracts of *Calotropis procera* and *Boscia senegalensis* at the concentration of 0.1 g/l after 24 h (Seck *et al.* 1993; Kébé, 2004). By comparison, to the recommended dose, our results showed a resistance of a portion of the individuals in these different areas to Deltamethrin resistance, which is more marked in Sedhiou. This deduction was in agreement with the results of Affo-Dogo (2013), who has determined resistance on the same product after the tests conducted on cowpea beetle. The survivors are obtained at all concentrations in Sedhiou, while in Saint- Louis, they are recorded only at the lowest concentration. This could result from a different use of the product in these localities. The Deltamethrin has had a low influence on adults of Sedhiou, these latter have probably implemented the mechanisms that enabled them to reduce the penetration of the product through the cuticle, leaving time to adults to mate. In addition, the use of doses under lethal could cause a phenomenon of infestation leading to the recurrence of the pest (Cohen, 2006). The Deltamethrin contributed to delaying the development of survivors. However, they could live longer in the two localities but in Saint- Louis, the expectancy life of females is reduced compared to that of the controls. The females' laying varied according to the locality and the concentration. In St -Louis, Deltamethrin did not influence the number of eggs laid; however, in Sedhiou the C3 concentration that represented the reference dose has reduced significantly the fertility of females. Thus, Deltamethrin would have at this concentration an inhibitory action on the reproductive potential of females. Low emergence rate is recorded compared to the controls. The sex-ratio declined but remained in favour of males for the lowest and the highest concentration; while in the other concentrations it increased and was in favour of females, which would increase the risks of an augmentation of the population. The development of the progeny is delayed under the action of Deltamethrin and even more with C1 concentration. As regards, the demographic evolution parameters, there was a diminution of the daily growth rate, a reduction of the number of female's descendants, the Lmax is elongated; in the contrary, the population evolved very rapidly, and particularly in Sedhiou with the C3 concentration.

CONCLUSION

This present study aimed to determine the level of resistance of *Caryedon serratus* according to certain formulations of insecticides of synthesis. Two types of formulations (powder and liquid) have been used on the adults of this beetle. The actions of these insecticides varied under the locality, the dose or concentration and the exposure time of the insect to the product. The resistance to insecticides has been more felt with the Deltamethrin in the locality of Sedhiou, which has recorded the lowest mortality rates and survivors at all concentrations while in Saint -Louis survivors were obtained only with C1 concentration and no survivors were recorded in Mpal. The same trend is noted with the Propoxur for which there are survivors only at low doses D1 and D2 in Sedhiou and just for D1 for the other localities. The monitoring of these survivors and their descendants has enabled us to see that their different parameters varied considerably with the effect of the two products. Among the strains studied, those of Sedhiou have presented the most reduced growth parameters. However, the reproductive potential of individuals of this locality is disturbed by the action of insecticides. Indeed, the number of eggs laid increased with D1 dose and decreased with the D2 dose for Propoxur; whereas for Deltamethrin, it increased with C1 and C5 concentrations and declined with C2 and even more with C3. According to our results, the locality of Sedhiou seemed to distinguish itself from the other regarding the level of resistance to insecticides, which has impelled us to ask the following question: how chemicals are used in this area. In addition, the correlations made between our results and those of studies conducted with plants biocides underline the interest of favouring the biochemical control as an alternative to chemical control and could generate satisfactory results and present less risks. To better identify the resistant strains of *C. serratus* to insecticides, the implication of genetic characterization is needed. Because of the resistance genes of this pest could be constitute an important tool for an integrated pest management.

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